LITTLE BLUE BOOK NO. 608
Edited by E. Haldeman-Julius

The Origin and Development of the Atomic Theory

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CHAPTER I

THE PYTHAGOREAN ATOMISTS

THE SIGNIFICANCE OF THE ATOMIC THEORY

It is safe to say that there is no more romantic story in the history of science than that of the origin and development of the atomic theory of matter. Dr. Robert A. Millikan has said that the physical principles laid down by Leucippus in the fifth century before our era might, with a few modifications and omissions, "almost pass muster today" ("The Electron," Page 7). The importance to modern students of sound knowledge of the teachings of the ancient Atomists was emphasized by Sir William Osler (1829-1919), who even went so far as to say that "the student of physics may know Crookes' tubes and their relation to Roentgen, but he cannot have a true conception of the atomic theory without a knowledge of Democritus; and the exponent of Madame Curie and of Sir J. J. Thomson will find his happiest

illustrations from the writings of Lucretius"[1]—the Roman exponent of Epicurus (342-270 B. C.), who revived the atomic theory of Leucippus and Democritus, despite the adverse criticisms hurled at this doctrine by the great Aristotle.

Le Sage observed that "if Epicurus had had but a part of the geometrical knowledge of his contemporary Euclid, and conceptions of cosmogony the same as many then living, he might have discovered the laws of universal gravity, and not only the laws, but, what was the despair of Newton, its mechanical cause" (*Lucrèce Newtonien,*" Berlin Academy, 1782).

Writing of the value to science and modern thought of the atomic theory of the early Greek philosophers, Professor Walter T. Marvin, of Rutgers College, points out that a theory can be significant in at least three ways, namely:— "(1) by destroying or inhibiting other beliefs; (2) by arousing interest in new problems and by suggesting new methods of investigation; (3) by what it itself enables us to explain correctly. This theory was most significant in destroying old beliefs or, to adopt a much used expression, in '*enlightening*'

[1] "Studies in the History and Method of Science," edited by Dr. Charles Singer, Oxford, 1917.

the cultured Greeks. A thoughtful Greek could hardly believe that the universe is a cloud of atoms moving about in accordance with necessary mechanical laws, and at the same time continue to believe the primitive traditions and superstitions of his people. The worship of the gods and the old magical rites and ceremonies must needs seem to him utterly ineffective and useless, valuable customs no doubt for their purely psychological influence upon the ignorant and unruly masses but of course absurdities for the cultured and disciplined man. Hence no wonder that the spread of this and the preceding cosmological theories would result, in a society such as that of the Greek world in the sixth and fifth centuries B. C., in a *radical enlightenment*. No wonder that their spread was opposed by men of conservative tendencies. In this first respect early Greek science and in particular the atomic theory were of great historical significance."[2]

THE ATOMIC THEORY OF THE PYTHAGOREANS

In the ancient Sanskrit literature of India (written prior to 500 B. C.), an atomic theory of matter is formulated by Kanada (literally "atom eater"—a term of derision), founder of

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[2] "The History of European Philosophy," Page 105, New York, 1917.

the Nyaga system of philosophy, and said to have been a pupil of Buddha. He states that the atoms are eternal and that the ultimate atom is simple.

Kapila, the leading exponent of the Sankhya philosophy, speaks of "five subtle" kinds of particles (atoms), and a substance akin to our luminiferous ether—the five particles being, no doubt, the "five elements" of the Laws of Menu; viz., earth, water, wind (air), fire and ether—this last the parent, so to speak, of all the other elements, through a process of successive transformations.

In the "Angutarra Nikaja," consciousness (mind) is mentioned as a sixth element, also atomic in structure.

In his "History of Hindu Chemistry," Sir P. C. Ray expresses the opinion that the atomic theory of the ancient Greeks was derived directly from the more ancient Hindu doctrine—a view upheld by the great German Sanskrit scholar, Dr. Max Müller, as also by some Greek scholars.

The atomic theory, the earliest known to have been worked out in detail, is that of the Greek philosopher Leucippus, of Miletus, Ionia; though the mantle of honor has fallen mostly

on the shoulders of his far better known pupil, Democritus of Abdera, Thrace.

But the Pythagoreans also were exponents of a form of atomic theory, and it seems probable that Pythagoras, a native of the island of Samos, was the first Greek to advance the doctrine of the discontinuity of matter. At least, none of his disciples ever claimed to have been the originator of this doctrine, and Pythagoras was born some time between 580 and 570 B. C., while the Atomic School of Leucippus was not founded until some time after 500 B. C. Unfortunately, Pythagoras did not commit his doctrines to writing, though a few of the so-called "Golden Sentences" may have been written by him. Most of them, however, are probably no older than the fourth century of our era. Moreover, these throw no light on the subject under discussion.

The first written exposition of the Pythagorean atomic theory was put forward by Philolaus, a native of Tarentum, South Italy. Only fragments of his work have survived, and of those ascribed to him some are undoubtedly spurious. But all of them are very old and contain valuable information concerning Pythagorean doctrines.

Porphyry (233-304? A. D.), a Syrian Neo-

Platonist, residing for some years in Alexandria, wrote a "Life of Pythagoras," and a few years later another "Life" of this philosopher appeared, this time from the pen—or stylus—of another Syrian and Neo-Platonist, Iamblichus. But these works contain much that is wholly mythical concerning Pythagoras.[3]

Our best sources of information are Plato (*Timaeus*), Aristotle (*Metaphysica and Physica, De Anima and De Coelo*), Diogenes Laertius (*De Vitis*) and Stobaeus (*Eclogarum physicarum et ethicarum*). From these authorities we learn that, according to the Pythagoreans, the cosmos was at a certain stage of its (cyclic) changes a compact, inert, spherical mass of lifeless matter, having no distinguishable parts. After a long period of quiescence the "void"—i. e., the limitless outer air—broke in upon the world, entering into "the heaven itself" as if it—the heaven—were breathing. The result of this cosmic inhalation was "a certain separation and definition of things that lie together" (Aristotle, *Physica*, iv, 6)—that is, a separation of the homogeneous mass into

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[3]Cf. Nauck, A., *Porphyrii Opusculati Selecta*, ed. 2, Leipsic, 1886; and *Iamblichi De Vita Pythagorica Liber*, ed. Nauck, Petrograd, 1884; Chaignet, *"Pythagore et la Philosophie Pythagoricienne,"* Paris, 1873. See also Cantor, *"Vorlesungen uber die Geshichte der Mathematik,"* I, 124 ff.

different "elements." These fragments were eventually ground into an all but infinite number of infinitesimal particles, or "monads," analogous to the "atoms" of Leucippus and Democritus.

Now, Philolaus was a famous geometrician as well as an eminent physician and astronomer. Hence he—and presumably Pythagoras before him—thought of these particles (or atoms) not in terms of various qualities, chemically considered,—as Anaxagoras (500-428 B. C.), who was not a Pythagorean, had done before Philolaus wrote—but in terms of form (shape) and number. Each of the various substances known to the ancient world as "elements"—generally recognized as compounds of the real elements since the eighteenth century only—was regarded as made up of particles of a certain geometrical configuration. Philolaus explained that the "element" earth was composed of cubical particles, fire of tetrahedra (pyramidal forms), and the "ether" was identified with the dodecahedron (particles having twelve plane faces, or twelve regular pentagons). In the *Timaeus* of Plato we find this conception further developed, bringing all the five regular solids into the theory. Thus, the octahedron was now assigned to air, and the

icosahedron (a figure having twenty equilateral triangular faces) to water.

Very interesting in this connection is the fact that the positions of the electrons in atoms (the real elements) are being referred to today in terms similar to those employed by the Pythagoreans. Take, for example, the following passage from *Science Progress* (London), July, 1922 (No. 65), Pages 21-22:

"The modifications proposed in the expressions for electric and magnetic forces allow of the electrons in [Sir J. J.] Thomson's model [atoms] to take up positions at rest at the corners of certain well-known polyhedra, such as the tetrahedron, the cube, the rhombic dodecahedron, the cubo-octahedron; and so in the sharing of electrons between atoms and the consequent fitting together of such models we have the explanation of certain facts of crystallography."

But we know now that "fire" is not an "element" composed of tetrahedral atoms; but the combustible portion of coal and wood is the real element *carbon*—and the carbon molecule *is* of tetrahedral form. (See Bragg, Sir W. H. and W. L., "X-Rays and Crystal Spectra.")

On the Pythagorean theory—as on that of Leucippus, and on the latest theories of today

matter is broken up into parts (atoms) that are in themselves unchangeable—apart from radioactivity—but produce by their changes of position in relation to one another all the substances of earth and of living organisms.

To illustrate this principle in terms of modern science: Add four electrons (two positive and two negative) to the hydrogen atom, and you have the element lithium; knock out of the lithium atom (composed of three positive and three negative electrons) one positive and one negative electron, and you have one atom of helium (composed of two positive and two negative electrons.) And *electrons are all alike*, except that some carry a charge of positive electrification and some a negative charge—each kind (species) of atom having an equal number of positive and negative charges, thus attaining stable equilibrium. (See Soddy, *The Interpretation of Radium*, 1922.)

Until quite recently it was believed that atoms could be disrupted only by temperatures higher than those obtainable in our physical laboratories, or by bombardment by electrons and helium atoms spontaneously expelled (always with enormous velocities) from radioactive substances. But this is now known to be an erroneous assumption. It was lately

discovered by P. M. Basset, engineer of the Sperry Gyroscope Company, and Dr. Louis Bell, that when carbon is brought to a temperature of 5,000° C., in an arc-light used in connection with their amazingly powerful searchlight, alpha particles (helium atoms) are liberated. Such discoveries may some day lead to the transmutation of "the baser metals into gold," thus fulfilling the dream of the alchemists of old.

Quite recently, Drs. Milliken and Bowen not only developed a method for "stripping" planetary (valence) electrons one by one from atoms, but these investigations also proved that Bohr's (simple) theory of electron orbits —which includes the statement that the energy developed when an electron jumps from one orbit to another is exactly proportional to the frequency (or wave-length) emitted—is correct. Professor Sommerfeld's theory explaining the cause of double lines in the spectrum of hydrogen and other elements was also verified experimentally. (See *The Scientific Monthly*, Pages 665-669, June, 1924).

An atom of mercury, for example, contains 80 positive charges (electrons) on its nucleus, and 80 negative outlying electrons. Were we able to expel two of its *protons* (positive elec-

trons), it would instantly become the metal platinum. If a negative ("planetary") electron were also taken from it, the mercury atom would then have lost two positive charges (electrons) and one negative; that is, one positive charge on the whole: and hence it would retain 79 positive charges on the nucleus and 79 outlying negative electrons—and thus *become gold!*

Thus, one element differs from another only in the number of electrons composing its atom. And this is only a more precise statement of the essential doctrine of the ancient Greek atomists.

Parmenides, the Eleatic philosopher, who was at the height of his fame about 475 B. C., declared that both motion and change of substance were illusory—that no substances ever transform from one to another. The Pythagoreans and the School of Leucippus admitted that there was, indeed, an element of elements that knew no change, no transformations; and they declared that this primal element was the stuff that *all* atoms are made of. Today we believe his primal element (atom) to be hydrogen—as was suggested by the English physician, William Prout, in 1815. In other words, we are being forced by the mathemati-

cal and experimental data to conclude that all of the 87 known species of atoms (or elements) are but compounds of the original (simplest) hydrogen atom, consisting of one positively charged nuclear electron and one outlying negative electron. However, there is ground for difference of opinion on this question, as shown by Sir Oliver Lodge in his recent article, "Within the Atom," *Scientific American*, November, 1923.

"Thought," comments Professor Alfred Weber ("History of Philosophy," Pages 43-44), "discovers in the atomistic hypothesis the middle term that unites Parmenides, who denies the great empirical fact of generation and change, and Heraclitus, who sacrifices being and its permanence to becoming,—thereby combining the two rival systems into a higher synthesis,—and lays the foundation for every rational explanation of the process of becoming. Henceforth philosophy no longer regards matter as a continuous mass, the essential properties of which are incessantly transformed. It breaks them up into parts that are in themselves immutable, but which continually change their relative positions. As a consequence, there can be both perpetual change in the aspects of matter (bodies) and permanance

in the essence and properties of matter. All change is reduced to change of place: *mechanism.*"

THE FIERY "MONADS" (ATOMS)

"Fire," with the Pythagoreans, as with the followers of Heraclitus of Ephesus (535-475 B. C.), is *the* element *par excellence;* and, as previously stated, was regarded by them as made up of excessively minute particles of tetrahedral (pyramidal) form (Philolaus). This "subtile element" was looked upon as the symbol of the divine principle in nature. They taught that this "fire" is concentrated in a central sun, "the hearth of the universe," "mother of the gods," "citadel of Zeus," etc., around which revolve the earth and the other heavenly bodies.[4] The soul of man is a portion of the world-soul, a spark of the celestial fire, and in this sense material.

Aristotle states (*De Anima*, i, 2) that some of the Pythagoreans held the solar corpuscles (atoms) to be souls, while others referred to that which set them in motion as the soul.

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[4]Thus laying the foundation for the true heliocentric theory, introduced by Aristarchus of Samos about 280 B. C.—a theory accepted and developed by Seleucus of Seleucia in Babylonia, but rejected in the following century by the greatest of the Greek astronomers, Hipparchus of Nicæa, discoverer of the "precession of the equinoxes," and author of a catalogue of 1000 fixed stars.

Schlottman's reading of this passage is: "The solar corpuscles are moved by a soul, and the soul is, generally speaking, the moving principle."

Professor Burnet calls attention to the singular power exhibited by the Pythagoreans in adapting their theories to conditions; and among certain radical changes in their point of view, he thinks the most remarkable is the way the religious side of the doctrine was gradually dropped. "The effort was made to clear the name of Pythagoras himself from the imputation of mysticism. We have the echo of this in the remains of Aristoxenos and Dikairchos, but it must be older; for in their day scientific Pythagoreans had ceased to exist. The statement that Hippasos of Metapontium was guilty of publishing a mystic discourse 'with the view of misrepresenting Pythagoras' (Diogenes, viii, 7) must go back to this generation of the school; for at a later date no one would have any interest in making it."[5]

According to Stobaeus (*Eclogarum physicarum et ethicarum*, i, 308), Ecphantus—an immediate successor of Pythagoras, according to

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[5]Burnet, Professor John, "Greek Philosophy," Vol. I, ¶70, Page 87, London, 1914. See also, by the same author, "Early Greek Philosophy," 2 ed., ¶¶138 sq.

Röth—was the first philosopher to explain the Pythagorean monads (atoms) as something corporeal. But this view is regarded by most authorities as being contrary to the doctrine of the Pythagoreans. While Ecphantus is included among the disciples of the School, his doctrine of material atoms as the original constituents of the Pythagorean "numbers," as well as of matter, cannot, according to Zeller, have been derived from his reputed master. Unlike the followers of Leucippus, Ecphantus believed, with Anaxagoras (500-428 B. C.), that the movement of the atoms (or monads), as well as the formation of the universe, was produced by mind or soul. Atoms, according to Ecphantus, differ among themselves in size, form and *force*. It is interesting to note that this philosopher had not only accepted as true the affirmation of Pythagoras that the earth is a sphere, but he knew also that it rotated upon its axis (Schiaparelli, "*I Precursori di Copernico nell' Antichita*," in *Memorie del Reale Instituto Lombardi*, xii).

Here, then, paradoxically enough, we find in the teachings of the idealistic Pythagoreans the roots of our modern theories of cosmogony and the atomic theory of matter. Their "particles" are qualitatively all alike, differing only in

form. By changes in their number and position these qualitatively homogeneous atoms form all the various substances of earth, sea and sky.

THE "SEEDS" OF ANAXAGORAS (500-428 B. C.)

The "seeds" (or germs) of Anaxagoras must also, in a sense, be considered "atoms." But, so far from being all alike fundamentally, for him each substance was supposed to be composed of its own peculiar particles, there being as many kinds of "seeds" as there are kinds of substances.

Whence came this more or less novel doctrine? Was it wholly original with the sage of Clazomeniæ? Leucippus, the founder of "the materialistic" atomic theory, was a contemporary of Anaxagoras, and both lived after the time of Pythagoras, and may have been indebted either to him or to suggestions from India for their fundamental physical conceptions, finding them, indeed, fully accordant with the primary postulates of the older Ionian physicists—Anaximines (508-524 B. C.), Anaximander (611-547 B. C.) and Thales (624?-548? B. C.). All of these believed that all elements are but compounds or transformations of one primitive element.

It is natural to inquire here how such "suggestions from India" could have reached

Greece. Professor Gompertz, while he does not discuss the possible Indian origin of the atomic theory, would have an answer to this question. He admits that the Greeks "owe to the Orient the elements of material civilization" and much of their science, art and religion to older civilizations. How were these transferred to Greece? This question, he recalls, brings up a striking parallel from the literary history of mediæval Europe. "Practically the entire fairy-lore of the Occident is derived from India. No one," he goes on to say, "disputes this assertion today"; yet, on the other hand, "no one as yet can give a completely clear account of the ways and means by which its journey was accomplished" ("Greek Thinkers," Page 95).

CHAPTER II

THE MATERIALISTIC ATOMISTS: LEUCIPPUS AND DEMOCRITUS

SOURCES OF OUR INFORMATION

While the Atomic Theory is usually identified with the name of Democritus, its real founder was Leucippus, as is attested by both Aristotle (384-322 B. C.) and his successor, Theophrastus. Diogenes Laertius, who flourished about 230 of our era, refers to Leucippus (De Vitis, ix, 46) as the author of "The Great Diakosmos" (or "The Great Order of the Universe"), in which were set forth the principles upon which he based his atomic theory. A treatise "On the Mind" is also mentioned, which appears to have contained in outline the psychology of the materialistic Atomists.

Of the works of Leucippus there remains but one extant fragment, in which Leucippus lays down in clear terms this universal rule: "Nothing happens without a cause, but everything with a cause and by necessity" (Aetius, Doxographers 321 B. 10).

Following in the footsteps of his master, Democritus also wrote a book "On the Order of the Universe," adhering, it would seem, very

closely to the views of Leucippus. The works of his master the great Milesian, were incorporated eventually in the collected works of Democritus.

No writer, subsequent to Theophrastus (born at Lesbos about 390 B. C.; died in 286 B. C.), pupil of and successor to Aristotle as head of the famous Lyceum at Athens, attempted to distinguished the teaching of Leucippus from that of his more brilliant disciple. Zeller remarks that "the work and even the name of Leucippus seems to have been pretty early forgotten by most writers in comparison with the riper and more exhaustive achievements of his disciple. The persistance with which he is ignored by Epicurus, the reviver of the Atomistic philosophy, and by most of the Epicureans, may have contributed to this.[1]

Of the once numerous writings of Democritus himself, only fragments remain, but these are highly important. The chief collector of the extant fragments was Mullach,[2] who places

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[1]Zeller, Dr. Edward, "Pre-Socratic Philosophy," Vol I. Page 209, London, 1883. (English translation by S. F. Alleyne and O. J. Reichel.)

[2]*Democriti Abderitae operum fragmenta*, Berlin, 1843. Cf. Liepmann, Hugo Karl, "*Die Mechanik der leucipp-democrit' schen Atome*," Berlin, 1885; and Liard, *De Democrito philosopho*, Paris, 1873; Lassewitz, "*Geschichte der Atomistik*," Hamburg, 1890.

Democritus first on the list of Greek philosophers for genius and knowledge, and thinks it probable that the great Aristotle himself may owe much of his reputation for learning to diligent perusal of the words of the sage of Abdera. Says he: "(Democritus), although in other things dissimilar, in his equal study of all the arts was most like the famous Aristotle. And I scarcely know whether the Stagirite did not owe to his reading of the works of Democritus his erudition, which surpassed that of all other philosophers."

Aristotle and some later historians make frequent references to his teachings, and according to Zeller, "with respect." Gompertz says that Aristotle confers "a crown of eulogy" upon Democritus "at the expense of Plato."

Professor Lange remarks, however, that "he cites him, for the most part, only when he attacks him, and this he by no means always does with a fitting objectivity and fairness. How often he has borrowed from him without naming him we do not know. Plato speaks of him nowhere, though it is a matter of dispute whether, in some places, he has not controverted his opinion without mention of his name" ("History of Materialism," page 18).

It seems to be quite possible that Plato knew

little or nothing of the writing of Democritus. At any rate, they were not well known in Athens before Aristotle's discussion of his theories. An extant Democritean fragment states that "I went to Athens and no one knew me." Professor Burnet says: "It is not clear that Plato knew anything about Democritus, for the few passages in the Timæus and elsewhere where he seems to be reproducing him are easily explained by the Pythagorean influences that affected them both. Aristotle, on the other hand, knows Democritus well; for he too was an Ionian from the north.

"It is certain, nevertheless, that the Democritean corpus (which included the works of Leucippus and others as well as those of Democritus) continued to exist; for the school maintained itself at Abdera and Teos down to Hellenistic times. It was therefore possible for Thrasyllos in the reign of Tiberius to produce an edition of the works of Democritus arranged in tetralogies just like his edition of Plato's dialogues. Even that did not suffice to preserve them."[3]

Besides being the favorite pupil of Leucip-

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[3]"Greek Philosophy," Vol. I, Pages 193-194, London, 1914.

pus, Democritus (according to Glaubus of Rhegion, a contemporary) had also Pythagoreans for teachers, including the astronomer, geometrician and physician, Philolaus, who was exiled from Italy in the first half of the fifth century B. C. because of his membership in the Pythagorean Order. Burnet thinks that this accounts not only for Democritus' geometrical knowledge but also "for other features of his system."

THE PHYSICS OF DEMOCRITUS.

We know that both Leucippus and Democritus regarded the atoms composing the various substances of the world as being homogeneous—i.e., all alike from a chemical standpoint, but differing from one another in point of size and in rich variety of form. Unlike the minute particles (homœomeries) of Anaxagoras, which were assumed to be infinitely divisible as well as qualitatively different for each substance, the atoms of Leucippus and Democritus were considered indivisible; hence the name *atoma* (atoms) (particles which cannot be cut, or further divided).

But while the atoms are described as "indivisible," because there is no vacuum in them,

this does not mean that they were regarded by Leucippus and Democritus as mere mathematical points, like the atoms of Boscovich[4] or the "point charges" (electrons) of some modern physicists. They were bodies of a definite magnitude, some larger, others smaller, but never of visible size (Sextus, *Mathematica*, vii, 139), much less, as asserted by Stobæus (*Eclagarum physicarum et ethicarum*, i, 348) "as large as a world." According to Simplicius (*Physica*, 18 a), Democritus taught that the atoms were physically indivisible, but he did not claim that they were *mathematically* indivisible.

The variety of substances and organisms seen on every hand is due entirely, according to Democritus—and also to Leucippus, whose views are expressed by Democritus—to the infinite variety of the atoms in form, size and *arrangement in space with reference to one another*—an anticipation of modern stereochemistry (the arrangement of the atoms of a molecule in space) and the work of van't Hoff

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[4]Boscovish, Roger Joseph, *Theoria Philosophae Naturalis*, etc., Vienna, 1758. A Latin-English edition of this work has been issued from the press of the Open Court Publishing Company, Chicago, 1923.

(1852-1911).[5] In all other respects the atoms are alike, and act on one another only by pressure or collision.

THE ATOMIC THEORY OF KNOWLEDGE

Man's sense impressions—color, sound, bitterness, sweetness, etc.—are merely the effect of the impact of atoms upon a particular grouping or arrangement of physically varied but essentially (chemically) homogeneous atoms, constituting our sense organs. Hence these sense qualities have no existence in themselves—are mere deceptive "appearances." "Only in opinion consists sweetness, bitterness, cold, color;

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[5]Van't Hoff was first to explain the cause of a known difference in their behavior toward a beam of polarized light of two distinct substances—both of which are called amyl alcohol—the chemical formation of which is identical (i. e., composed of the same number and kinds of atoms)—by a difference in the order in which the four different groups of molecules are arranged in space about the central carbon atom; the arrangements in the two cases being such that one molecule has the same arrangement as the mirror image of the other—equivalent to the difference between a right-hand and a left-hand glove. Democritus could, possibly, on his theory, have arrived at such an explanation; whereas Aristotle, on his theory of the elements, could not possibly have done so—any more than could Empedocles (495-436 B. C.) have done so with his "four elements."

As for the primal substance ("air") of Anaximines (588-54 B. C.) and the "fire" of Heraclitus (535-475 B. C.), Dr. Gompertz contends that these were implicitly recognized as being composed of "minute, imperceptible particles" ("Greek Thinkers, Vol. I, Page 323).

in truth there is nothing but the atoms and empty space," says Democritus.

The great Protagoras (born about 500 B. C.), also of Abdera, a contemporary of Leucippus and Democritus, had taught that all sensations are equally true for the sentinent subject—i.e., if a substance tastes sweet to a given person, it *is* sweet. For Democritus sweetness and bitterness did not reside as such in the substance tasted, but were merely subjective effects produced on the palate of the consumer. Taste is partly dependent upon the shape of the atoms composing the food (they held) and partly upon the particular taste-sense of the individual. Thus to the normal (or average) person honey has a sweet taste, whereas the same honey to a jaundiced person has a bitter taste.

Parmenides had already declared that taste, colors, sound and the like were only names, standing for no objective qualities. Democritus agreed that sensations *represent* nothing external to ourselves, though they are *caused* by something outside us. For example, what we call pungency, tartness, bitterness, saltiness, etc., were impressions produced on the palate by atoms of a certain shape—sharp, rough, pointed or hooked particles of matter produc-

ing an effect of pungency or acidity. Atoms with smooth surfaces form substances which ordinarily impress the senses agreeably. From this we learn the effect upon our palates of certain substances, but these sensations tell us nothing of the true nature of the substances tasted.

"By the senses," says Democritus, "we in truth know nothing sure, but only something that changes according to the disposition of the body and of the things that enter into it or resist it" (Fragment 9). True reality lies beyond sense impressions; "truth is in the depths" (Fragment 11). Our ideas represent our impressions, and are not direct reproductions of the external objects themselves, "the inner essence of which is concealed from us."

This ancient theory of the differences of taste depending on differences in the shapes—or roughness or smoothness — of the particles composing substances prevailed even well into the eighteenth century of our own era; dictionaries of the period still defining acidity, for example, as due to sharp, pointed particles. Today we still admit that atoms are qualitatively homogeneous—but by "atoms" we now mean electrons, the constituent electrical charges which make up the "atoms" of the

chemist. Differences in the number of electrons in atoms confer upon them qualitative (chemical) differences, though all atoms of any one element are chemically alike—are homogeneous. Differences in the number of spatial arrangement of these atoms (in groups or "molecules") constitute both physical and chemical differences in substances, i.e., in compounds. Quite different substances are produced by combinations of precisely the same *kinds* of atoms, but in different proportions.

Take from a molecule of certain substances one single atom, and they may be changed from a compound necessary to life and growth into a deadly poison. Phosphorus is an element, and thus contains but one kind of atoms; but some (common) phosphorus is yellow and some (amorphous) is red, varying with the spatial distribution of the atoms in the molecules composing the phosphorus.

But the properties (or quality) of a compound are not merely the *sum* of the qualities of the different kinds of atoms composing its molecules (a molecule being the smallest possible quantity of a given substance or compound. Water, for example, is not merely the addition of the qualities of one atom of oxygen to those of two atoms of hydrogen (H_2O). It

is something quite different from either of these two elements. And just so the color of blue sulphate of copper is not a mere mixture of the colors of sulphuric acid and copper. Again, the experiments of Dr. P. W. Bridgman[6] showed that while the application of ordinary pressures to ice causes it to melt, the application of high pressures to water causes it to freeze, and that "there are at least five different kinds of ice, only one of which we are ordinarily familiar with" (Page 192). Paraffin, under pressures as high as 20,000 atmospheres, "becomes more rigid than soft steel" (Page 188). Water, heretofore regarded as absolutely incompressible, was found to decrease in volume about twenty per cent with a pressure under 12,000 atmospheres.

Professor W. T. Marvin could well say, in considering the shortcomings of ancient atomic theories, that "even with our wealth of physical information we cannot yet explain by a rigorous atomistic mechanics water transforming into ice or a stick of wood burning, not to mention the phenomena of living organisms."

Modern science recognizes that not only different *results* may be obtained under different

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[6] "On the Properties of Matter under High Pressure," Annual Report of the Smithsonian Institution, 1918.

conditions, but that *absolutely new qualities* emerge at critical moments, both in the domain of chemistry and in the phenomena of biology. We talk now of *emergent evolution*. "We live in a world in which there seems to be an orderly sequence of events. . . . But the orderly sequence, historically viewed, appears to present, from time to time, something genuinely new . . . If there be only regrouping of pre-existing events and nothing more—then there is no emergent evolution."[7]

In the gradual transition from non-living to living matter, an entirely new and peculiar type of energy—"biotic energy" *emerges*, which is not explicable merely on the grounds of increasing complexity of atomic structure. "We call things *living* because of the energy changes they exhibit, and not because they are complex chemically or physically." A dead animal is just as *complex* as a living organism. What is missing is "biotic energy" — the form of energy which gives rise to the distinctive energy-transformations "which we aggregate together under the term *life*." The recognition

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[7]Morgan, Professor C. Lloyd, "Emergent Evolution," Pages 1-2, London, 1923. Cf. Mill, J. S., "Logic," Book III, Chapter VI, §2; Lewes, G. H., "Problems of Life and Mind," Vol. II, Problem V, Chapter III, Page 412.

of this fact, however, does not commit us to the outworn doctrine of "vitalism" or to the Aristotelian "entelechy."[8]

Leucippus and Democritus, of course, were not troubled with the problems raised by such phenomena as we have just been considering, since they knew nothing about them. For the founders of Atomism, a multiplicity of substances, living matter, and consciousness could readily be accounted for by the varied combination of variously formed atoms, physically considered. What would be their astonishment to learn that tens of thousands of different substances are actually composed of only four kinds of atoms—viz., hydrogen, oxygen, nitrogen and carbon! Yet for them *one* element, qualitatively considered, was sufficient to produce all that is — including the "soul" — provided this primal matter existed in an infinite number of shapes and sizes of atomic dimensions.

DEMOCRITEAN COLOR THEORY

"We have no exact information," says Professor Gompertz, "as to which bodies in the theory of Democritus were simple and which

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[8]See on this point Moore, Dr. Benjamin, "Biochemistry—A Study of the Origin, Reactions and Equilibria of Living Matter," especially Chapter IX, Pages 125-137, London, 1921.

were complex," but he adduces evidences to show that "the infinite multiplicity which Democritus recognized in the sizes and shapes of atoms did not arise from his incompetence to perceive or to conjecture a complex in an apparently simple body."

He remarks that the Democritean theory of color started from the assumption of four primary colors—white, black, red and green. "These, with the exception of green, which had taken the place of yellow, were likewise the primary colors in the scheme of Empedocles." But all other colors "were designated as *mixed*, and we see that all the numerous bodies which were not equipped with one of the four primary colors must have been of a composite nature. That is to say, they must have included other than merely homogenously elementary particles. . . . The statements about the atomic forms underlying the several tastes give rise at first impression (to the idea that) each of the countless 'juices' or materials of taste is composed of homogeneous atoms possessing the size and shape required for the purpose.

"But this, we plainly perceive, was not the opinion of Democritus. His own view of the mixed colors cries against it. The homogeneity

of the atoms was admissible in the case of white salt, but it was not admissible in that of yellow-gold honey or of brownish-yellow human bile. It is true that he must have referred the sweetness of the one and the bitterness of the other to the presence of the atomic forms by which these impressions were produced. But yellow and brown were mixed colors in his theory; and he must accordingly have inferred that honey and bile alike contained atoms of other forms as well."

Professor Gompertz therefore concludes that "the true meaning of those statements should therefore be expressed as follows: 'In all substance of mixed colors at least the kind of atoms which lends them their specific taste is merely the predominant and preponderant kind, and without wasting more words on this subject, Theophrastus, who is our best authority for Democritus' theory of sensation, relates that this doctrine was expressly taught by him'."[9]

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[9]Gompertz, Opus citum, Pages 333-334. (Authorized English translation, from the German edition of 1896, by Laurie Magnus, M. A. (Oxon.), London, 1906.

CHAPTER III

THE ELEATIC VIEW

One of the problems that early perplexed the human mind was that of motion. Parmenides, of the Eleatic school, could not conceive of movement of bodies without vacuous space, and for him there could be no vacuum, since the universe is a *pienum*—the All, the One. Hence there could be no motion, movement of bodies and physical changes being mere delusive appearances.

Leucippus granted that he, likewise, could not conceive of the motion of bodies unless there was empty space for them to move in. But motion he recognized as a fact of nature, as a reality. The Eleatics must, therefore, he said, be in error in supporting the premise that "there is no vacuum." Given empty space, motion followed.

Neither Parmenides nor Leucippus introduced the conception of the vacuum. It was a pre-existing doctrine fervently attacked by Parmenides and supported on logical grounds by Leucippus. "Nor," says Professor Gompertz of Leucippus, "did he do more than to refine and to raise to the dignity of a self-sustained

system the atomic theory which existed before him, though in a rude, rudimentary and imperfect shape."

Given atoms of various sizes and forms, their movement in vacuous space was taken as much for granted as their existence. Just as matter itself had no beginning, and can have no ending, so the natural and original condition of atoms was a state of motion. The state of rest was no more "natural" to the Atomists than was the state of motion. They knew nothing of the doctrine which regards matter as an "inert mass." Matter for them was essentially active and non-quiescent, as it was centuries later for Bruno, Bacon, Leibnitz, Spinoza, and as it is in our own times for all physicists. For *energy* is synonymous with *motion*, and matter itself is but a collection of *energy units* (in constant motion).

DEMOCRITUS' THEORY.

According to Democritus the atoms fall with varying degrees of rapidity, the heavier particles faster, the lighter with less speed, the heavier overtaking and striking against the lighter ones. To quote Lange's succinct statement:

"As the atoms are of various shapes, and the collision will not take place in the center of the atoms, then, even according to the prin-

ciples of modern mechanical science, revolutions of the atoms on their axes and lateral motions will be set up. When once set up, these lateral motions must ever become more and more complicated, and as the collision of constant new atoms with a layer of atoms already in lateral motion constantly imparts new forces, so we may suppose that the motion will continually increase. From the lateral motions in connection with the rotation of the atoms are then easily produced cases of retrogressive movement. If now, in a layer of atoms so involved, the heavier—i. e., the larger—atoms continually receive a stronger impetus downwards, they will finally be collected below, while the light ones will form the upper stratum."[1]

Aristotle said that if there could be such a condition as space devoid of substance (matter), then in such a vacuum all bodies, light or heavy, would fall with equal velocity, which he considered an absurdity. For him the differences in the speed of falling bodies are entirely dependent upon differences in the density of the medium—air or water—through which they fall toward the center of the earth. Epicurus agreed with the Stagirite on the

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[1]Lange, Frederick Albert, "History of Materialism," Vol. I, Page 25, London, 1892.

point of equal velocities in a non-resisting medium. But Aristotle not only denied the possibility of the existence of a void anywhere, but asserted that in such a void — were a vacuum possible — no motion could take place!

Epicurus believed that all atoms, of whatever weight, would fall with equal velocity in a vacuum, in simple parallel lines. They are in everlasting movement, originally a perpetual, equable falling through the boundless infinity of vacuous space, with an incomparably greater speed than that of light-rays; though he believed that these traverse the distance from sun to earth in an instant.[2]

While it is true that in infinite space there is neither an "up" nor a "down," the fact remains, as Epicurus in effect observed, that man considers his head "up" and his feet "down," and a body as being relatively distant from, or as near or on or within, the earth. So the atoms do converge at the earth, falling downwards unless met by bodies which, by a particular movement and weight, drive them to one side or upwards, or in a spiral or whirling motion—"the commencement of the formation of worlds." But if the movement of atoms is

[2]That 498 seconds, over eight minutes, are required for this transmission of light is a discovery of the eighteenth century.

in straight parallel lines, and all move in the vacuum with equal velocity, how could one atom drive another "to one side or upwards"?

Just here is where the weakness in the atomic theory is introduced by Epicurus. Democritus accounted for the collision and rebound of atoms under law, by a *cause*, not by chance. Epicurus threw away the cause and introduced "chance collisions." But no atom was ever deviated from its flight in parallel lines by "chance"—in this case a wholly metaphysical invention. No worlds, no suns or planets could be built up on the theory of particles falling through infinite space in parallel rectilinear paths. There must be collision and recoil of atoms in order that the lateral and whirling movements, or vortices, should be set up, which were supposed to cause the atoms to combine according to their shape, size, and weight, the heavier forming the denser portions of the earth, the lighter constituting the atmosphere.

This difficulty did not escape the astute mind of Lucretius. But in attempting to solve what is really an insoluble problem—the development of worlds under the conditions stated—the great Roman poet only made bad matters worse. For here he introduced the dogma of free will applied to the falling atoms. They

were made to deviate from their parallel lines by a voluntary movement!

And it appears that this was done on the authority of Epicurus himself: "In these errors," says Lange, "Democritus probably had no share; and yet we shall judge them more leniently if we reflect that, even to our own day, the essence of the doctrine of the freedom of the will, with whatever metaphysical subtlety it is elaborated, consists simply of the uncertainty and perplexity of phenomenal appearances." Again: "Whilst, therefore, it is one of the most important efforts of recent materialism to deduce the whole mass of voluntary movements from mechanical causes, we find Epicurus adopting a quite incalculable element into his system."[3]

For Democritus a "chance" occurrence would be a causeless event, and this he could not allow under his law of "necessity." An efficient cause produces always appropriate and calculable results under given conditions, and these results are always uniform, predictable occurrences, given knowledge of the mechanical factors involved.

To the earlier Atomists it seemed clear that particles which are alike in weight and in

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[3]Lange, *Op. cit.*, Page 142.

form would "naturally," when whirled about in a vortex, be brought to the same location; and because of their peculiar shape, become entangled one with another. Since some atoms were supplied with hooks or even with balls and sockets, some with mortice or dovetail, others with sharp, rough or involuted edges, what more "natural" than that groups or combinations of atoms should be formed, even to the cohesion of some atoms in places not suitable to their nature, resulting in the formation of compound bodies?

Some atoms, indeed, were "unsociable," having no means of mutual attachment; hence their combination was effected by enclosing them in a shell formed by the "social" particles. Some atoms had means for attachment at two points, which accounts, in part, for the greater or less mobility of the various atoms. The soul consists of the finest and smoothest atoms, akin to those of fire; and since they penetrate the whole body, their motions give rise to the phenomena of life. All objects project into space images of themselves, composed of atoms, which strike against the senses, and are perceived by similar atoms—"like atoms are perceived by like."

These assumptions were wholly unacceptable

to the critical mind of Aristotle,[4] as well as to his distinguished disciple, Strato of Lampsacus, teacher of Ptolemy Philadelphus. The Roman Stoic, Cicero, regarded the Democritean theory of cohesion and compounding of substances as wholly fantastic.[5] Yet the critics of Democritus had no better theory to offer in its place, since they, like the Atomists themselves, had no conception of the electrical, chemical or gravitational attraction of bodies for each other, or of the fact that the pressure of the atmosphere cause the ascent of fire, vapor and heated molecules in general.

To the foregoing objections, others might be offered, but we add only that in modern terms, the impact of indivisible and indeformable atoms upon one another could not produce the required movement of elementary masses. For "if the atoms are rigid, transmission of motion through impact is impossible; if they are elastic, they are then deformable and composed of parts, which is contrary to the hypothesis and implies forces of cohesion and elasticity."[6]

Democritus, though he was the greatest

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[4] *De Cœlo*, iii, 4; *Generatio et Corruptio*, i, 21; and elsewhere.

[5] *Academica*, ii, 38, 121.

[6] Rougier, Louis, "Philosophy and the New Physics," Pages 7-8, London, 1922.

physicist of his age, could not, of course, be expected to anticipate our modern objections to his doctrine—or his master's doctrine. The immortal Newton (1642-1727) himself, even Dalton (1766-1844), founder of the modern chemical atomic theory (as distinguished from the *physical* atomic theories of his predecessors), could not anticipate the advances that have made possible the relentless criticism of modern physics and chemistry. Newton, Boyle and Huygens had no idea that the "atoms" of their conceptions were occupied mostly by "empty space" (using this phrase in its popular meaning—modern science recognizing no actually empty space: for all space contains a gravitational "ether" if not an electromagnetic field of energy).

Thus the "atom" of the chemist is a highly elastic body—highly resilient. Moreover, thanks to the genius of Professor Frederick Soddy, of Oxford, and of Sir F. W. Aston, we now know that what we considered but three years ago to be a homogeneous element—e.g., lead chlorine, carbon, iron, etc.—is in many cases—if not in all cases excepting hydrogen and helium—a compound body containing particles of different weights (atomic mass). On the other hand, as previously stated, we are

reverting to the Democritean theory that all atoms are composed of but one primitive element, the hydrogen atom. And the hydrogen atom in turn is composed of—*energy;* and energy itself is apparently of atomic structure. All energy is, in the last analysis, electrical in nature, the stuff that lightning, the stars, fire, rocks and metals, the bodies of plants and animals—perhaps the mind of man—are all made of.

With these facts in mind, let us return to Democritus, whose errors—the errors of his age—we may now regard with due allowances.

"SOUL ATOMS

With Democritus, as with Pythagoras and Heraclitus, fire had a special importance, though it was not, as asserted by some of the ancient writers, regarded by him as an element. The primitive substance, the source of all things, whether fire, earth, air or water, was the world of homogeneous atoms, eternal, unchangeable. Fire, composed of minute, round, smooth atoms, was, on account of its mobility, the living and moving principle of nature, though not the direct *cause* of motion. But because of the fiery, mobile nature of its atoms, they become a secondary cause of additional motion, from their impact with and recoil from

less mobile atoms. Sensation and consciousness are possible because of the extreme mobility of the fiery atoms. They are the "soul atoms," but sensibility and consciousness arise only as the result of relatively large aggregations of these excessively minute bodies.

"EFFLUENCES"

In order to account for the mutual action or influence of bodies upon one another, when separated by space,—the void,—the Atomists had recourse to the Empedoclean theory of "effluences," or emanations, which were supposed to be emitted by all bodies (Aristotle, *Generatio et Corruptio*, i, 8). Penetrating the organs of sense, they excite the appropriate sensation, and, in the case of the brain, they produce images or ideas of things. Hence sensation is the only possible source of knowledge, the origin of all thought being the passage through the sense organs of "effluences" from external objects or organisms, acting mechanically, by contact.

But while affirming that sensation is the source of all knowledge, Democritus, nevertheless, agrees with the Pythagoreans and Socrates in rejecting sensation as such as a source of knowledge. He distinguishes be-

tween a "bastard" (*skotie*) knowledge obtained through the special senses and a true-born (*gnesie*) knowledge, obtained by direct-contact of external atoms with the body's "soul atoms." These are not concentrated in the brain nor are they dependent upon the organs of sense. They are diffused throughout the entire organism, and come into direct contact, without the intervention of the deceptive sense organs, with the reality outside our body.

"Poor Mind," he makes the senses say (Fragment 125), "it is from us thou hast got the proofs to throw us with. Thy throw is a fall."[7]

As Burnet points out, the "true-born knowledge is of the same nature as the "bastard," and "Democritus refused, like Socrates, to make an absolute separation between sense and thought," the former being, 'after all, not thought, but a sort of inner sense, and its objects are like the 'common sensibles' of Aristotle." In the "bastard" knowledge, Democritus included sight, hearing, smell, taste, touch. "True-born" knowledge was obtained

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[7]Burnet, Dr. John, *Op. cit.*, Page 153; and Note 2, Page 113. Dr. Burnet is Professor of Greek at St. Andrews University, Scotland

directly by the diffused soul atoms from the external objects, and thus made them known as they really are. All phenomena of life and mind are due to the motion of the mobile fiery atoms. Even where Democritus speaks of "the Divine," he means merely the fiery soul atoms; not a personal being of any kind.

Where there is a large aggregation of the soul atoms, there reason appears, itself a physical phenomenon. Democritus recognized no *Nous* (Anaxagoras) or World-Soul (Plato). or Deity (Aristotle). The only motive force of the world is gravity, the soul being a secondary cause of motion only by virtue of the fiery atoms' being most easily moved by pressure and contact. "Spirit" is "only one substance moving side by side with others."[8]

Every act of the individual, every occurrence in nature, has its efficient cause from which it follows by necessity—or, as we should say, under natural law. All change in things must be reduced to an altered combination of atoms—to new forms and arrangements in space, under the law of "necessity."

The soul is material and disappears with the disintegration of the body, though there exist invisible beings all around us in the air.

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[8]Zeller, *Op. cit.*, Vol. II, Page 253.

But these invisible beings are material bodies also, composed of the finest atoms. At times they project images of themselves which affect our soul atoms, rendering these aerial beings, for the time, visible bodies.

CHAPTER IV

EPICURUS AND LUCRETIUS

ATOMS NOT INFINITE IN VARIETY

Epicurus (341-270 B. C.) agreed with Democritus in assuming that the atoms are infinite in number, but he denied that they were infinitely various in shape, though their variety of form was conceded to be very great, some smooth and round—like the soul atoms and those of fire—some rough and pointed, others again branched or hooked. While the number of forms is limited, there is an unlimited number of each form. None of these variously formed atoms was ever created, and none can ever be either created or destroyed. "Out of nothing, nothing comes."

MANY INHABITED WORLDS

Since space is infinite in extent and the atoms infinite in number as well as varied in shape and weights, there must also be innumerable inhabited worlds (as asserted by Democritus), displaying the greatest diversity; yet some of them may nevertheless be exactly alike, since like causes acting upon like bodies or complexes must inevitably produce like effects.

Metrodorus, of Chios, declared that "a single

ear of corn on a wide-spreading champaign would not be more wonderful than a single cosmos in the infinitude of space."

MAN'S GREATEST ENEMY

Study of Democritus convinced Epicurus that the greatest enemy of mankind is superstition, fear of imaginary gods and of punishment hereafter, making of man a mental slave. Epicurus was not a lover of science for science's sake. He regarded its pursuit as having no greater justification than that through reasoning and observation it would free mankind from the fetters of supernaturalism, thus leaving an open road to peace and happiness. Pleasure is the highest good, and the highest form of pleasure is derived from cultivation of our mental faculties.

"Protected as it was by the emperors, the (Epicurean) school destroyed what remained of the crumbling edifice of polytheism, and at the same time attacked the new religion and the supernatural Christian."[1]

ON THE GODS

In supporting his atomic theory of cosmology, biology and ethics, in refutation of the theological hypotheses of the Platonists and the Stoics, based, they claimed, upon "a study of

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[1]Weber, Alfred, "History of Philosophy," Page 139.

nature and the laws of logic," Epicurus offered what he regarded as logical evidence against the doctrine that the world was ever created or that it is the product of beneficent design. Professor Weber summed up the doctrine of Epicurus, as derived from the writings of the Poet, Lucretius; the biographer, Diogenes Laertius; and other authors of lives of the philosophers of ancient Greece, in the following words (translated by Dr. Frank Thilly, Professor of Philosophy in the University of Missouri):

"The absolute creation and absolute destruction of the world are [according to both Democritus and Epicurus] out of the question. Creation in the proper sense of the term is impossible. In order to convince ourselves that the world is not the work of the gods, we have simply to consider the nature of its alleged creators, on the one hand, and its imperfections, on the other. Why should such perfect and supremely happy beings, who are self-sufficient and have no need of anything, burden themselves with creating the world? Why should they undertake the difficult task of governing the universe?

"Let us, however, suppose for a moment that the world is their product. If they have created it, they have created it either eternally or in

time; in the former case, the world is eternal; in the latter we have two possibilities: either creation is a condition of divine happiness, and then the gods were not supremely happy for an entire eternity, inasmuch as they did not create the world until after the lapse of an eternity of inaction; or, it is not, and in that case, they have acted contrary to their innermost essence. Moreover, what could have been their purpose in making it? Did they desire a habitation? That would be equivalent to saying that they had no dwelling-place for a whole eternity, or at least, none worthy of them. Did they create it for the sake of man? If they made it for the few sages whom the world contains, their work was not worth the trouble; if they did it in order to create wicked men, then they are cruel beings. Hence it is absolutely impossible to hold that creation is the work of the gods.

"Let us examine the matter from the standpoint of the world. How can we assume that a world full of evils is the creation of the gods? What have we? Barren deserts, arid mountains, deadly marshes, uninhabitable arctic zones, regions scorched by the southern sun, briars and thorns, tempests, hailstones and hurricanes, ferocious beasts, diseases, pre-

mature deaths; do they not all prove that the Deity has no hand in the government of things? Empty space, atoms and weight, in short, mechanical causes, suffice to explain the world; and it is not necessary for metaphysics to have recourse to the theory of final causes."[2]

Just as astrologists blame the stars for the individual's short-comings—while at the same time holding on to the doctrine of free will, by assuring us that "the stars incline but do not compel"—and credit the astral bodies for his good traits and successes, exactly so the ancient Greeks placed responsibility for man's derelictions and misfortunes—as well as for his happy achievements—on the gods. Minerva's influence endowed the individual with intelligence; Venus infused the passion of love; Apollo dispersed manly beauty, health and happiness; Mars involved peoples in wars; while Mercury was the god of mathematics, inventions, business transactions, etc. Without

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2Weber, *Op. Cit.*, Pages 136-137. Epicurus was the author of about three hundred writings, according to Diogenes Laertius, but only his Letters, preserved by this historian, and fragments of a work discovered at Herculaneum remain. For the rest we are dependent on the *resume* presented by Lucretius and the quotations found in Greek authors. As Weber remarks (Page 135), "neither polytheism nor Christianity had any interest in preserving his numerous writings."

denying the existence of the gods, Epicurus, as we have seen, did seek to show that the Olympian divinities were not in any way concerned with terrestrial affairs.[3]

Though the gods are dead, we cannot yet say, with Henley,

I am the captain of my soul.
I am the master of my fate,

For modern man has within his own physiological "world" real substitutes for the imaginary gods of Olympus, which really "incline" if they "do not compel," "behavior." While the gods have been all but forgotten, and the "fateful" stars have been reduced to vast incandescent masses of helium, hydrogen, calcium, iron, etc., the endocrine (ductless) glands still largely control or alter personality; though these bodies are but constellations of atomic systems, with electrons for sun and planets, each revolving in an all but inscrutable cosmos of its own.

These still mysterious glands are to-day the real "astral influences"—acting under "necessity"—which confer upon us manly beauty and

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[3]Lange expressed the opinion that Epicurus really believed in the existence of the gods, reverenced them for their perfection: "these careless and painless gods did in fact represent, as it were, an incarnated ideal of his philosophy" (*Op. Cit.*, Vol. I, Page 101.)

intelligence, or, perhaps, a dwarfed body and an inbecilic brain. The pituitary body, originating tens of millions of years ago in the roof of the mouth of some lowly chordate (lancelet stage), in Cambrian times, and now attached to the base of man's brain, has taken the place of Minerva and Apollo; the gonads and the thymus have absorbed the functions of Venus; the adrenals, the combative "influence" of Mars; while the thyroid makes of us—or "inclines" us to become—poets, radicals, "uplifters,"—or maybe, mere lovers of the limo light![4]

Surely this character-building "by necessity" would have delighted the soul of Democritus and brought joy to the heart of his great disciple Epicurus, who introduced an element of chance into Atomism only to bridge what was to him an impassable gulf between the laws of mechanics and observed phenomena.

This insistence of the ancient Atomists on the necessity of attempting to account for all natural phenomena as the result of uniform, immutable, universal "necessity" or law is one of the greatest conceptions handed down to us from antiquity—a monument to the human

[4]See Berman, Dr. Louis, "The Glands Regulating Personality," New York, 1922; Cunningham, J. T., "Hormones and Heredity," London, 1922.

mind equalled only by the attempt to correlate all qualitative differences of substances (atoms) with differences of size, shape and position in space (with relation to one another) and with movement.

Gompertz does not hesitate to declare that this grand work of the ancient Atomists "is destined to survive all changes of opinion and thought." Furthermore, all exact knowledge of nature "rests entirely on this attempt to reduce qualities to quantites, or, to speak more precisely, to establish fixed relations between the two. Mathematical physics was contained there as in a germ, and modern research took its starting-point thence. Galileo, Descartes, Huygens,—they all followed the same path. 'I do not believe,' declared Galileo, 'that anything else is required than magnitudes, shapes, quantities, and slow movements or swift, to produce in us tastes, smell, sounds.' "[5]

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[5]Gompertz, *Op. cit.*, Page 349.

CHAPTER V

POST-CLASSICAL ATOMISM

The two principal links in the chain which binds the world of the ancient Greek (and *one* Roman) Atomists with those of our own times are Descartes (1596-1650) and Gassendi (1592-1655). Gassendi revived and ably supported the atomic theory of Epicurus; while Descartes resuscitated the mechanistic conceptions of the Greek Atomists on the basis of a corpuscular theory of matter, corresponding in many respects to the doctrine of Democritus.

The work of Leucippus connects through Descartes and Gassendi, Huygens, Boyle and Newton, directly with that of Higgins and Dalton, founders of the modern chemical atomic theory.

Dalton had already adopted a physical atomic theory, based no doubt on the work of his illustrious predecessors, and upon his own thorough study of the gases of the atmosphere, before he formulated his chemical atomic hypothesis. He opposed the prevailing belief that the various gases exist in the atmosphere in a state of chemical combination, asserting that the atmosphere is a physical mixture.

In 1805, he extended his atomic hypothesis to the explanation of chemical phenomena. His

first postulate was, of course, that all matter is made up of small particles; these he found possessed the power of attracting (and holding) other particles. He therefore concluded that these invisible particles never subdivide in taking part in chemical changes, and that all atoms of any one element must be alike. But the atoms of the different elements vary in weight, form and combining power. He established the rule, already assumed by William Higgins (1789), that different atoms tend to combine in the porportion of atom to atom.

When a compound was composed of two elements only, it was presumed to be binary; that is, since water, for example, was known to be composed of hydrogen and oxygen, it was supposed by Dalton that it *must* consist of one atom of each of these elements; as was also assumed in the case of ammonia, which he knew to be a combination of hydrogen and nitrogen. Now we know that one atom of hydrogen combined with one atom of oxygen forms, not water, but oxide of hydrogen; while the combining of *two* atoms of hydrogen with one atom of oxygen forms water.

Dalton established the fact that elements combine only in *definite proportions*—e. g., that oxygen and hydrogen will combine only in the

proportion of 8 to 1. Had Dalton known that a molecule of water contains *two* atoms of hydrogen, and *one* of oxygen, he would have known that *one* atom of oxygen must weigh *sixteen* times—instead of eight times—as much as *one* atom of hydrogen. *One part* of hydrogen *by weight* does combine with *eight parts by weight* of oxygen, but this does not prove that the portion of hydrogen in water contains only one atom. Since it contains two atoms, instead of one, then, in order to preserve the relative combining (or "equivalent") weights of the two substances, we must assume that the *atomic* weight of oxygen is 16, for the *combining* weights of elements represent the relative (not actual) weights of the atoms. And each element has its own fixed combining weight, ascertained by experiment.

Water, then, is not a mere mixture or combination of hydrogen and oxygen, in the sense that a pound of hydrogen and eight *and a half* pounds of oxygen will, when exploded, produce 9½ pounds of water. Combination would indeed be effected, but there would be a residue in the container of just one-half pound of oxygen. The mass of oxygen that has combined will weigh exactly eight times as much as the hydrogen; and now we know that the water formed will contain exactly twice as many

atoms of hydrogen as there are oxygen atoms present in the combination, uniting not only "one by one," but, in this case, two to one. What the law of definite proportions proves is that chemical combinations always take place *between atoms*.

But there is also a law of *multiple proportions*. It is found that when one element forms more than one compound with a second element, the quantities of the first element which combine with the combining weight of the second element are always simple multiples—never fractions—of the combining weight of the first element.

We have seen that the *atomic* weight of oxygen is 16—i. e., 16 times heavier than the lightest element, hydrogen, which is therefore (on the relative scale of atomic weights) 1. But the *combining* weight of oxygen is 8—i. e., eight *parts* of oxygen will combine with so many parts (combining weight) of some other element. Suppose we take for example nitrogen. Now the *combining* weight of nitrogen is 14, and its *atomic* weight is also 14. Fourteen parts of nitrogen will combine therefore with eight parts of oxygen. But fourteen parts of nitrogen will also combine with four simple multiples of eight parts of oxygen,

forming in all five different compound substances. For example:

14 parts of nitrogen combine with 16 or 2x8 parts of oxygen.
14 parts of nitrogen combine with 24 or 3x8 parts of oxygen.
14 parts of nitrogen combine with 32 or 4x8 parts of oxygen.
14 parts of nitrogen combine with 40 or 5x8 parts of oxygen.

John Dalton advanced a theory satisfactorily to explain why in successive compounds the amount of oxygen goes up in jumps, and why this jump in each case is equivalent to the combining weight of oxygen. The regular jumps in the case of the five nitrogen compounds simply mean that one more atom has entered, in each successive case, into combination. These combining weights, as we have seen, simply represent the relative weights of the various elements. "Atomic weight" is merely the name given by Dalton to the relative combining weights of the atoms. He had no information as to how many atoms actually combine in making a compound, much less of the actual weight of the single atoms of the elements.

Nor did he know *why* atoms combine at all, in any proportions, but, being a thorough-going Newtonian, both his physical theory and his chemical theory have a common basis in New-

ton's doctrine of mutually repulsive atoms. If an element A units with an element B, the repulsion of the atoms of B from one another must tend, he thought, to the formation of a binary compound. "Binary compounds must first be formed, then ternary, and so on, till the repulsion of the atoms of B refuses to admit any more."[1]

While we have traveled quite a distance in atomic and chemical theory since the days of John Dalton (1766-1844), it is to the everlasting credit of this (at the time) obscure and poverty-stricken teacher of mathematics and physics that he gave us, in 1808, "A new System of Chemical Philosophy" which unites the atomic theory of modern science, first advanced by his admirers and contemporaries, Baron J. J. Berzelius (1779-1848) and Sir Humphrey Davy (1778-1829).

Little did Dalton dream that the "atomic weight" of the elements is equivalent to the number of *electrons* in each atom of a given substance![2] Or that the atomic *number* of an element, arranged (successively) in the order of their atomic *weights*, from 1 (hydrogen) to 92 (uranium), is an index to the number of positive electrical charges on the atomic nucleus, around which revolve in "planetary orbits" an equivalent number of negatively charged *electrons*—the real building-stones of the Universe.

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[1] *Nicholson's Journal*, 29, 147, 1811.

[2] On this point, see Lodge, Sir Oliver, "Within the Atom," *Scientific American*, November, 1923.